Functional Relationship between the Energy Consumption and the Greenhouse Gas Emissions in Nigeria

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ABSTRACT

Emissions from Greenhouse Gases (GHGs) have become an issue all over the world, owing to their harmful effects in the environment. Estimating emissions has become a problem in developing countries like Nigeria. Energy consumption is a major source of emissions, particularly in densely populated countries like Nigeria. In this research, we established the functional relationship between the energy consumption and the GHGs emissions based on IPCC 2006 revised guidelines. We demonstrate it using data of energy consumption from 2005 to 2018 in Nigeria National Petroleum Corporation, (NNPC) bulletin, 2019 and used this data to estimate GHGs based on the carbon content of the energy and the fraction of carbon that is oxidized, emission factors, and energy density of the fuel. Microsoft Excel 2013 was used to analyze the data collected. We found that a total of 445572.2298 kmt and 64898.837 kmt GHG was emitted from combustion of gasoline and diesel, respectively, in Nigeria from 2005-2018, it was also found that 87.29 % of the total GHGs was as a result of the consumption of gasoline as fuel. CO^2 emissions accounted for 99.37 % of the projected total quantity of GHGs released into the atmosphere. By the sectoral method, we discovered that the transportation sector produces the most gasoline and diesel emissions in Nigeria.

(Keywords: greenhouse gasses, energy, consumption carbon dioxide, methane gas, nitrous oxide, emission factor)

INTRODUCTION

Accounting for the amount of greenhouse gases (GHG) emitted is paramount since there is a rising scientific agreement that states increase in man-made sources of emission of greenhouse gases contribute to global warming (Giwa, 2014). These gases influence not only global climate change but also international economic and political situations (Meng et al., 2016). Gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halocarbons are called greenhouse gases (GHGs). They tend to build up in the atmosphere and have a lengthy residence duration in the atmosphere, ranging from decades to centuries. Surface warming of the land and oceans is caused by higher GHG concentrations. Through feedback processes in the atmosphere, oceans, and land, these warming effects are indirectly increased.

Climate change affects temperature extremes, precipitation patterns, storm location and frequency, snowpacks, river flow, water availability, and ice sheets, all of which might have a substantial impact on biological and human activities that are sensitive to the climate (Nordhaus, 2007). Akpojotor, et al., 2016 and Giwa, et al., 2017 developed models that estimate the amount of GHG emitted using reference approach only of IPPC, 2006. For this research, we developed a model to estimate the amount of GHG emitted from combustion of gasoline and diesel in Nigeria using both approaches (Reference and Sectional Approaches) of Intergovernmental Panel on Climate Change's guideline 2006 (IPCC, 2006).

Here, energy means gasoline and diesel and only three kind of GHG''s were considered (i.e. CO_2,

CH_4 and N_2O). Because CH_4 and N_2O are gases which contribute significantly to total CO_2-equivalent emissions of GHGs from the lifecycle of conventional and alternative transportation fuels and technologies.

This paper is organized as follows. In Methodology, we describe and establish the relationship between the GHG's and energy combustion. Following that, we present the results and discussion of the developed relationship. We then demonstrate the reference approach of Tier 1. In the following section, we present the total GHGS emitted from gasoline and diesel consumption. Following that, we present analysis of sectional approach. Our paper concludes with the presentation of conclusions for the work.

METHODOLOGY

To determine the functional relation between the energy consumption and GHGs emission (CO_2, CH_4 and N_2O) from all sources of combustion we estimated base on the IPCC (2006) revised guidelines for national GHG emission inventories, which gave that the calculation of CO_2, CH_4, and N_2O emissions from energy combustion may be achieved through three levels namely as Tier 1, Tier 2, and Tier 3 subject to the obtainable data.

Tier 1 technique is a top-down method used to estimates of the emissions from the carbon content of mainly fossil fuels, when the estimation is for the entire fuel delivered to the country, it is regarded as Reference Method and if it's for activities, it is known as Sectorial Method. Therefore, for this research, we adopt both methods (i.e. Reference and Sectorial Method) in determining the emission estimate of the GHG's.

The quality of these emission parameters varies depending on the volume. The carbon content of the energy determines the emission factors for CO_2, CH_4,, and N_2O. Combustion circumstances (efficiency, carbon retained in slag and ashes, and so on) are mostly irrelevant. Therefore, GHGs emissions can be estimated accurately to an extent based on the total amount of energy combusted and the averaged carbon content of the energy. Based on this we formulate the functional relation between the energy consumption and GHGs emission which are presented in Equations (1), (2), (3), and (4).

The CO_2 emissions, E_{co_2} associated with energy consumption are a function of the volume of energy consumed x_{ij}, the density of the energy consumed ρ_j, carbon content of the energy η_j and the fraction of carbon that is oxidized to CO_2, for CH_4 emission E_{CH_4}, for each type of energy combusted, is a function of the volume of energy consumed x_{ij}, the density of the energy consumed ρ_j and emission factor of CH_4 σ_{ij}, while for N_2O emission, E_{N_2O} is also a function of the volume of energy consumed x_{ij} the density of the energy consumed ρ_j and emission factor of N_2O β_j.

The equations 1, 2, 3 represent the emission of CO_2, CH_4, and N_2O, respectively. CO_2 eq. describes the amount of CO_2 units that has similar global warming potential (GWP) than one unit of the substance concerned (Inter-governmental Panel on Climate Change (IPCC). The Fourth Assessment, Emission Factors for Greenhouse Gas Inventory (2018) states that methane (CH_4) is 24.5 CO_2eq and nitrous oxide (N_2O) is 320 CO_2eq. Equation (4) gives the total greenhouse gases emission that has similar global warming as CO_2 (tCO_{eq}).

$$E_{co_2} = \sum_i \sum_j \eta_j \rho_j x_{ij} \times 44/12 \quad \textbf{(1)}$$

$$E_{CH_4} = \sum_i \sum_j \sigma_j \rho_j x_{ij} \quad \textbf{(2)}$$

$$E_{N_2O} = \sum_i \sum_j \beta_j \rho_j x_{ij} \quad \textbf{(3)}$$

$$tCO_{eq} = \left[1 \times \left(\sum_i \sum_j \eta_j \rho_j x_{ij} \times 44/12 \right)_{CO_2}, 24.5 \times \left(\sum_i \sum_j \sigma_j \rho_j x_{ij} \right)_{CH_4}, 320 \times \left(\sum_i \sum_j \beta_j \rho_j x_{ij} \right)_{N_2O} \right] \quad \textbf{(4)}$$

RESULTS AND DISCUSSION

Table 1 and Table 2 give the volume of gasoline and diesel consumed in liters and used of equations (1, 2, 3, and 4) to estimate the emission of CO_2, CH_4, N_2O and CO_2eq in kmt, respectively, for the period of 14 years in Nigeria. Taking ρ_j as 0.74 and 0.832 for gasoline and diesel respectively, carbon content of the energy η_j as 0.84 and the fraction of carbon that is oxidized to CO_2 as 3.67, emission factor of CH_4 σ_{ij} 0.0173 kg for gasoline and 0.0051 kg for diesel, and emission factor of N_2O β_j as 0.0036 kg, 0.0048kg for gasoline and diesel respectively.

Figure 1 gives a view of the consumption of gasoline and diesel in Nigeria. It can be observed from Figure 1, the volume of gasoline consumed decreased from 8644260000 liters in 2005 to 8306985000 liters in 2006, increase by 8859802000 liters in 2007 and witness a reduction from 2007 to 2009 (6876577000 liters). There was an increase of 9090470000 liters in 2010 and decrease to 8042354000 litres in 2011 and increase again to 8391032000 litres in 2012 and slightly decrease from 2012 to 2014 with 6913444000 litres in 2014. The amount of gasoline consumed in the country has quickly grown since 2014, reaching 18694064000 litres in 2018. Also, it could be observed from Figure 1, that diesel consumption showed a gradual reduction pattern from 2368000000liters in 2005 to 1017689000 liters in 2018. The highest quantity of diesel consumed was recorded in the year 2005 with a value of 2368000000 liters while the lowest volume was in the year 2015 (247189000 liters).

Table 1: Amount of Gasoline Consumption with the GHG's Emitted.

Year	Gasoline (Litters)	Emissions in kmt			
		CO_2	CH_4	N_2O	tCO_2eq
2005	8644260000	19719.91	110.6638165	23.02830864	29348.93969
2006	8306985000	18950.49	106.346022	22.12980804	28203.82563
2007	8859802000	20211.62	113.4231852	23.60251253	30080.74659
2008	7206729000	16440.51	92.26054466	19.19872606	24468.24306
2009	6876577000	15687.34	88.03393875	18.31920113	23347.31297
2010	9090470000	20737.83	116.3761969	24.21701208	30863.9092
2011	8042354000	18346.80	102.9582159	21.42483106	27305.35205
2012	8391032000	19142.23	107.4219917	22.35370925	28489.1815
2013	7822127000	17844.40	100.1388699	20.83814633	26557.63866
2014	6913444000	15771.45	88.50591009	18.41741482	23472.48359
2015	8059131000	18385.07	103.1729951	21.46952498	27362.31322
2016	10998373000	25090.28	140.8011711	29.29966567	37341.61002
2017	13330814000	30411.21	170.6610808	35.5132885	45260.69971
2018	18694064000	42646.24	239.3214073	49.8009865	63469.97393
Total	1.31236E+11	299385.3818	1680.085346	349.6131356	445572.2298

Table 2: Amount of Diesel Consumption with the GHG's Emitted.

Year	Diesel (litters)	Emissions in kmt			
		CO_2	CH_4	N_2O	tCO_2eq
2005	2368000000	6352.79936	10.0478976	9.4568448	9422.13655
2006	1649749000	4425.897125	7.00021496	6.58843761	6564.256905
2007	1384956000	3715.518408	5.8766453	5.53096028	5510.660705
2008	1273203000	3415.710812	5.40245497	5.0846635	5066.00191
2009	648417000	1739.553675	2.75136301	2.58951813	2580.014154
2010	1336361000	3585.1492	5.670447	5.33689129	5317.303979
2011	1750465000	4696.094988	7.42757309	6.99065702	6965.000108
2012	1013223000	2718.244268	4.29930783	4.04640737	4031.556361
2013	1113305000	2986.741255	4.72397578	4.44609485	4429.776914
2014	551338000	1479.113046	2.3394374	2.20182344	2193.742365
2015	247189000	663.1512335	1.04887236	0.98717399	983.5508918
2016	664908000	1783.795235	2.82133763	2.65537659	2645.630899
2017	1291770000	3465.521803	5.48123846	5.15881267	5139.878941
2018	1017689000	2730.225519	4.31825796	4.06424279	4049.326319
Total	16310573000	43757.51593	69.2090234	65.1379043	64898.837

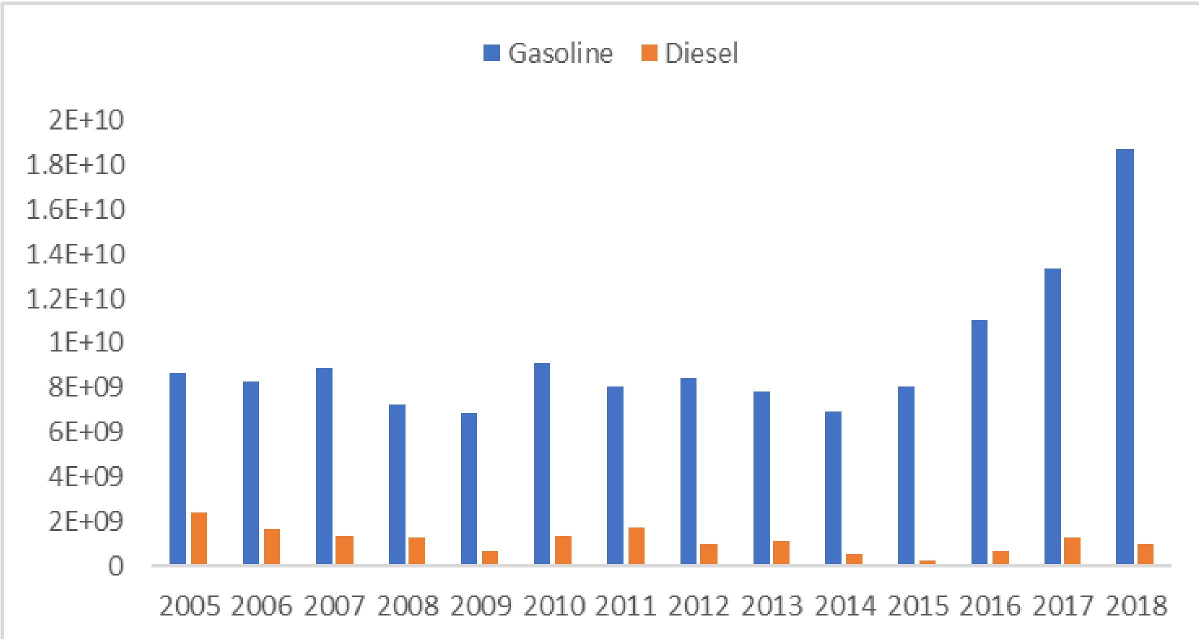

Figure 1: Volume of Gasoline and Diesel consumed in Nigeria from 2005 to 2018.

REFERENCE METHOD

Nigerian Greenhouse Gas Emissions from Gasoline and Diesel Use

To demonstrate using the functional relationship between the energy consumed in liters and GHGs emission in as kilometric tons (kmt), we considered the whole two major energy consumed in the country as distributed by marketing companies in Nigeria from January to December for the years 2005 to 2018, as reported by Annual Statistic Bulletin (ASB) of Nigerian National Petroleum Corporation (NNPC). Therefore, the apparent consumption for each product is its total distribution for that year which are then converted into the CO_2 CH_4 and N_2O emissions in kmt by taking into account Equations (1), (2), and (3), as shown in Tables 1 and 2 above.

These CO_2 CH_4 and N_2O emissions are on a yearly base is plotted as shown in Figure 2 and Figure 3 for the volume of gasoline and diesel consumed respectively. An inspiring observation is that; the bars vary in that there is a there is an increment of CO_2 CH_4, and N_2O emissions every year. Instead, the graph depicts fluctuations of the CO_2 CH_4, and N_2O emissions over the period of the 14 years, that is, there is decrease in some years and increase in others in the emission estimated for Nigeria.

However, it is observed in Figure 2 that from the CO_2 CH_4, and N_2O emission estimates of 19719.91 kmt, 110.6638165 kmt, and 23.02830864 kmt, in 2005 to 42646.24 kmt, 239.3214073 kmt and 49.8009865kmt in 2018, respectively. There is over 53% increment of the emission from gasoline consumption in Nigeria. Also in Figure 3, it could be seen that the CO_2 CH_4 and N_2O emission estimate of 6352.79936 kmt, 10.0478976 kmt, and 9.4568448 kmt in 2005 to 2730.225519 kmt, 4.31825796 kmt, and 4.06424279 kmt in 2018, respectively, which shows a decrease of approximately 75% emission from diesel consumption in Nigeria.

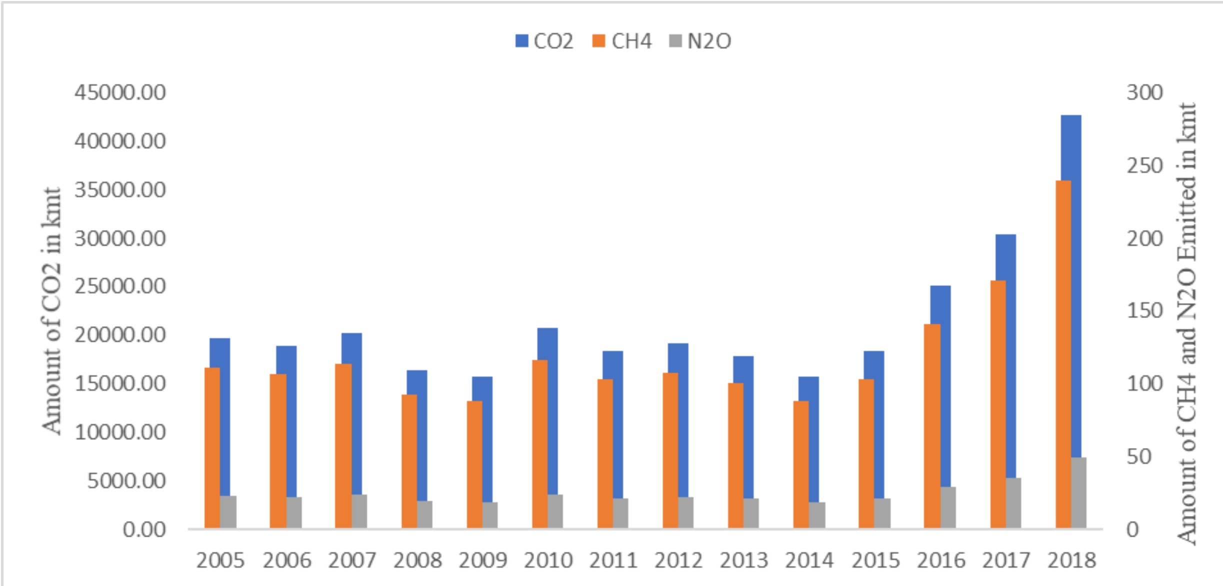

Figure 2: Amounts of CO_2, CH_4, and N_2O Released from Gasoline Consumption in Nigeria from 2005 to 2018.

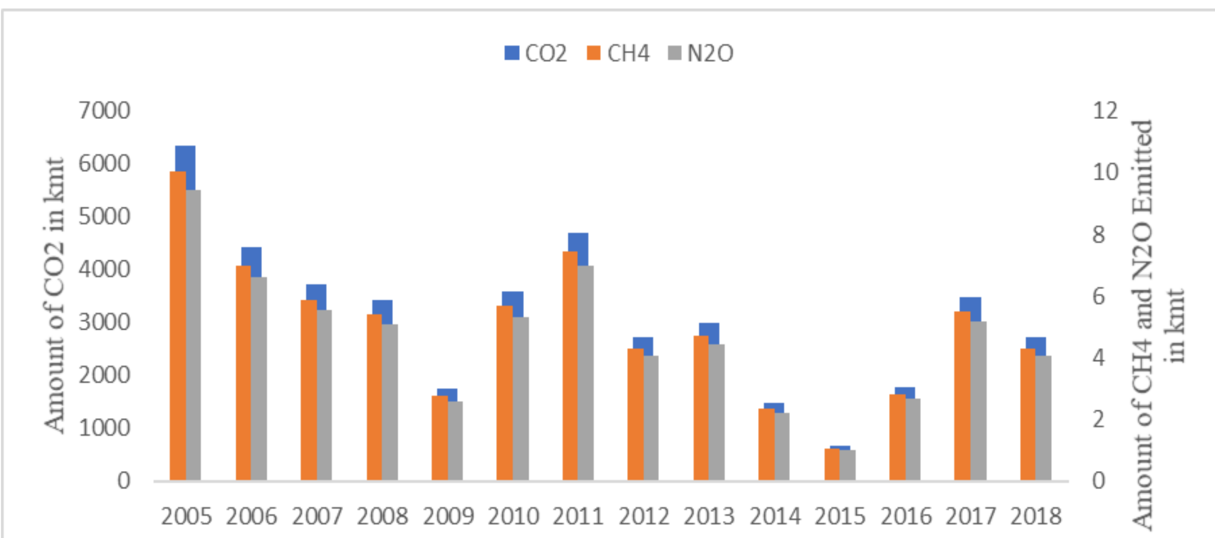

Figure 3: Amounts of CO_2, CH_4, and N_2O Released from Diesel Consumption in Nigeria from 2005 to 2018.

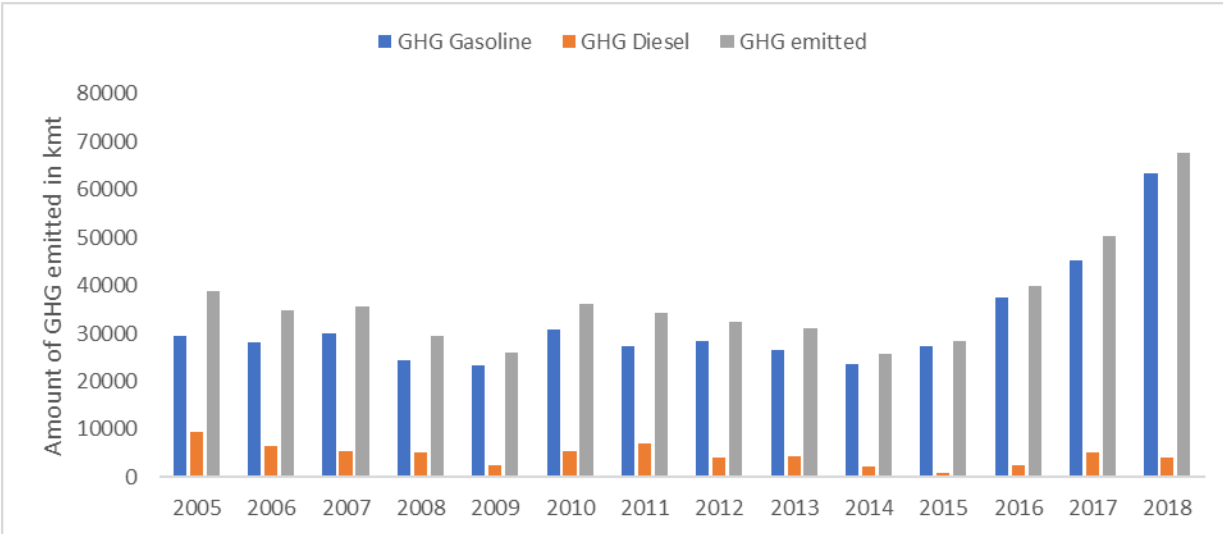

Figure 4: Amounts of Greenhouse Gases Released from Petroleum Products Consumption in Nigeria.

Total GHGs Released as a Result of Gasoline and Diesel Use

The estimated amount of GHGs emitted from the consumption of gasoline and diesel was 445572.2298 kmt tCO_2e and 64898.837 kmt CO_2e, respectively (Tables 1 and 2).

From Figure 4, it is clear that the quantity of GHGs released as a result of the consumption of gasoline is far more than that of diesel. This can be linked with the volume of gasoline consumed during the period in view compared to that of diesel. A total of 510471.0668 kmt tCO_2e of GHGs was estimated to be released into the environment due to the consumption of 1.31236E+11 liters of gasoline and 16310573000 liters of diesel for the 14 -year period in the country. From Tables 1 and 2, it was estimated that 87.29 % of the total GHGs was as a result of the consumption of gasoline as fuel. Of the estimated total amount of GHGs emitted into the environment, CO_2 emission accounted for 99.37% of the amount.

Analysis of Sectional Approach

Tables 3 and 4 show the result of sectional approach in validating the proposed functional relationship between the energy consumed in liters and GHGs emission in kmt, we considered seven (7) sectors in the country, two major petroleum products (Gasoline and Diesel) distributed by marketing companies in Nigeria from January to December for the years 2005 to 2018 as reported by (ASB, NNPC). Therefore, the apparent consumption for each product is its total consumption for each sector (Energy Commission of Nigeria MAED 2019) for 14 years which are then converted into the CO_2, CH_4, and N_2O emissions in kmt by taking into using Eq. (1), (2) and (3).

These CO_2, CH_4, and N_2O emissions are on a sectional base is plotted as shown in Figure 6 and Figure 5 for the volume of gasoline and diesel consumed for each sector, respectively. Also, the curve is not a smooth direct variation in that there is a different of CO_2, CH_4, and N_2O emissions for every sector. The graph depicts fluctuations of the CO_2, CH_4, and N_2O emissions as the sectional energy consumption varies, that is, some sectors consumed energy more than other sectors in Nigeria.

Table 3: Gasoline Consumption from Seven Sectors and the Gases Emitted for 14 Years.

SECTORS	Gasoline (Litres)	Emissions in kmt			
		CO_2	CH_4	N_2O	tCO2eq
Transportation	1.04989E+11	239508.3054	1344.068277	279.69051	356457.7838
Services	7874169720	17963.12291	100.8051208	20.976788	26734.33379
Household	18373062680	41913.95345	235.2119484	48.945839	62380.11217
Total	**131236162000.00**	**299385.38**	**1680.09**	**349.61**	**445572.23**

Table 4: Diesel Consumption from Seven Sectors and the Gases Emitted for 14 Years.

SECTORS	Diesel (Litres)	Emissions in kmt			
		CO_2	CH_4	N_2O	tCO_2eq
Agriculture	67464933.78	153.905864	0.863686082	0.179727	268439.113
Manufacturing	5081746590	11592.8462	65.05651985	13.53777	20219979
Mining	24414481.2	55.6960724	0.312554188	0.06504	97143.8242
Construction	787887774.4	1797.38632	10.08653929	2.098933	3134960.39
Transportation	7907365790	18038.8522	101.2300968	21.06522	31462956.2
Services	1942589244	4431.57445	24.8690275	5.175058	7729451.49
Household	499103533.8	1138.59092	6.38952344	1.329612	1985904.41
Total	**16310572348**	**43757514.2**	**69209.02**	**65137.9**	**64898834.4**

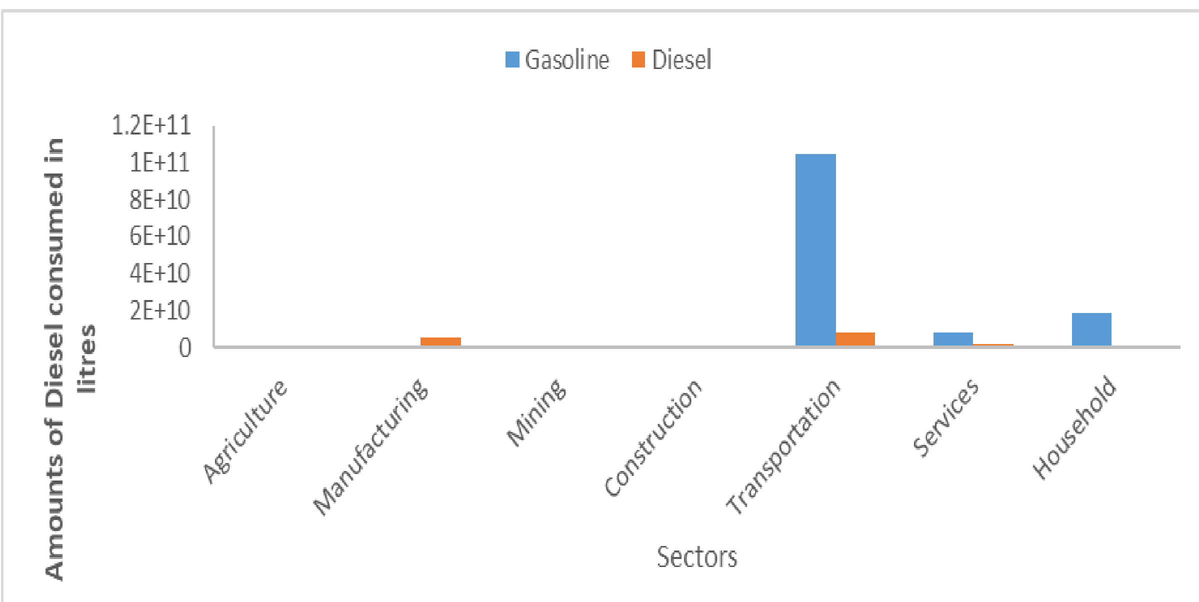

Figure 5: Volume of Gasoline and Diesel Consumed by Sectors in Nigeria from 2005 to 2018.

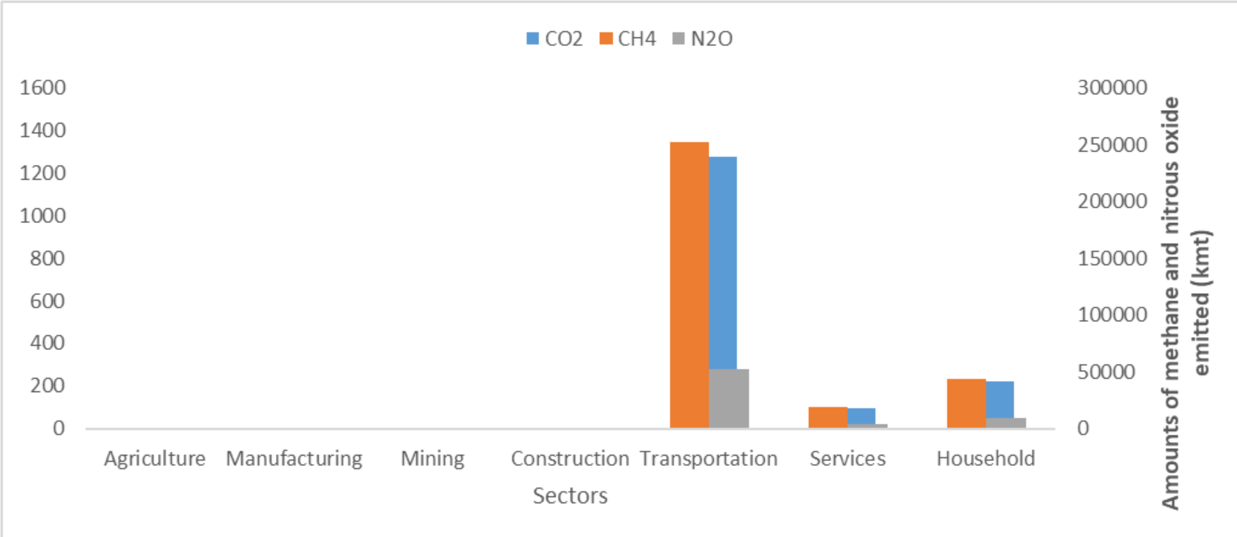

Figure 6: Amounts of CO_2, CH_4 and N_2O Released from Gasoline Consumption in Nigeria from 2005 to 2018 for Seven Sectors.

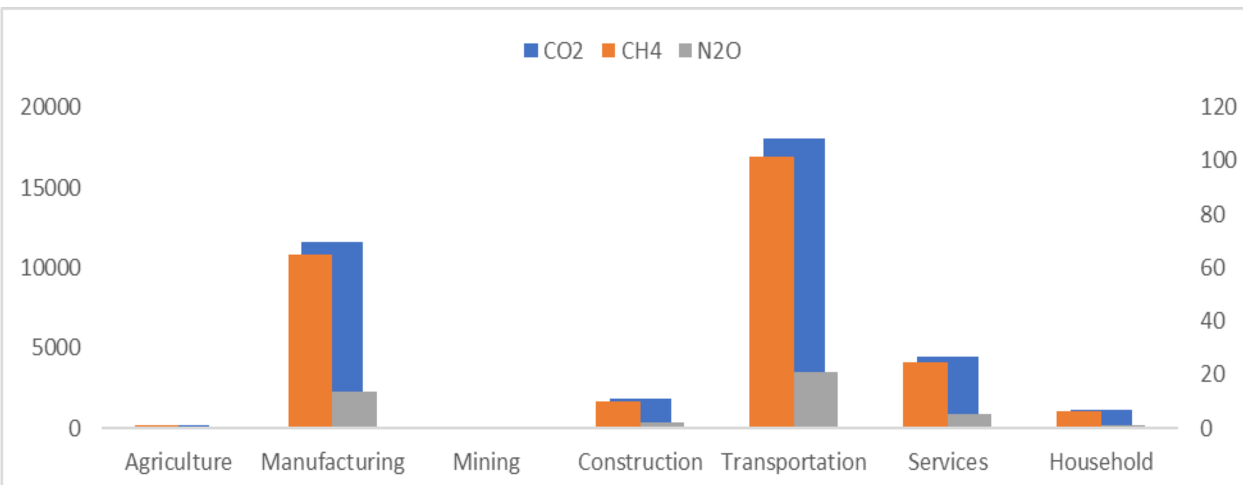

Figure 7: Amounts of CO_2, CH_4 and N_2O Released from Diesel Consumption in Nigeria from 2005 to 2018 for Seven Sectors.

CONCLUSION

This study adapts and adjust both Reference and Sectional approaches of IPCC 2006 (Tier 1) in developing a model that estimate the amount of CO_2 CH_4, N_2O, and tCO_2eq emitted through the combustion of energies. Microsoft of Excel 2013 Version 3.4. was used to estimate based on the models developed. We found that a total of 445572.2298 kmt and 64898.837 kmt GHG was emitted from combustion of gasoline and diesel, respectively, in Nigeria from 2005-2018. It was also estimated that 87.29 % of the total GHGs was as a result of the consumption of gasoline as fuel. Of the estimated total amount of GHGs emitted into the environment, CO_2 emission accounted for 99.37 % of the amount. In sectional approach we found that transportation sector account for the highest emission from gasoline and diesel in Nigeria. Therefore, we conclude that these models could be to account for the GHG emitted in the country or some sectors from the combustion gasoline and diesel.

REFERENCES

1. Akpojotor, G.E., M.O. Ofomola, and Z. Ezoukumo. 2016. "Estimated Inventory of Carbon Dioxide (CO_2) Emission in Nigeria from Three Major Petroleum Products from 2000 TO 2014 using a Modified Reference Approach". *Nigerian Journal of Science and Environment*. 13 (1).

2. Bolsen T., J.N. Druckman, and F.L. Cook. 2015. "Citizens', Scientists', and Policy Advisors' Beliefs about Global Warming". *The annals of the American Academy of Political and Social Science*. 658: 271-295.

3. Giwa, Sulaiman, and Nwaokocha. 2017. "Inventory of Greenhouse Gases Emissions from Gasoline and Diesel Consumption in Nigeria". *Nigerian Journal of Technological Development*. 14(1). Doi: http://dx.doi.org/10.4314/njtd.v14i1.1

4. Giwa, S.O. 2014. *Baseline Black Carbon Emission Inventory for Gas Flaring in the Niger Delta Region of Nigeria*. LAP LAMBERT Academic Publishing: Saarbruken, Germany.

5. Intergovernmental Panel on Climate Change's (IPCC) [Online]. Available: http://www.ipcc.ch/

6. IPCC Fourth Assessment, Impacts. 2007. "Intergovernmental Panel on Climate". UN IPCC: New York.

7. IPCC. 2018. "Fourth Assessment, Emission Factors for Greenhouse Gas Inventory, 2018

8. Meng Qing-Chun, Xiao-Xia Rong, Yi-Min Zhang, Xiao-Le Wan, Yuan-Yuan Liu, and Yuzhi Wang. 2016. "Collaborative Emission Reduction Model Based on Multi-Objective Optimization for Greenhouse Gases and Air Pollutants". *Plos One.* 11(3): e0152057. doi:10.1371/ journal.pone.0152057

9. Nordhaus, W.D. 2007. "The Challenge of Global Warming: Economic Models and Environmental Policy". Available online at http://nordhaus.econ.yale.edu/dice_mss_072407_all.pdf

10. Nigerian National Petroleum Corporation (NNPC). 2019.http://www.nnpcgroup.com/PublicRelations/OilandGasStatistics/AnnualStatistcBulletin/MonthlyPerformance.aspx

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